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Title of the Invention: Liquid crystal display device

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SPECIFICATION

1. Title of the Invention Liquid crystal display device

2. Scope of Claims

(1) A liquid crystal display device of an active matrix driving type which is provided with a pixel electrode substrate on which a switching element is provided and a common electrode substrate characterized by forming an insulating layer having a flat surface on a surface of the above mentioned pixel electrode substrate, and a pixel electrode on the above mentioned flat surface of the insulating layer to be connected to the above mentioned switching element through a contact hole provided on the insulating layer.

(2) The liquid crystal display device according to claim 1 characterized by forming an electrical separation region of the pixel electrodes in an upper region of a data electrode of the switching element.

3. Detailed Description of the Invention

[Field of the Industrial Use]

The present invention relates to a liquid crystal display device, and in particular, relates to a liquid crystal display device which can prevent deterioration of display quality caused by nonconformity of an orientation of a liquid crystal.

[Prior Art]

A liquid crystal display device is expected much as one of flat panel displays in place of CRT. Further, since the power consumption of the liquid crystal display device is very small in comparison with other kinds of sorts of display devices utilizing light emission, it is suitable to apply to a small-sized display device driven by battery, for example a very small-sized TV or the like. Therefore, researches are energetically made in such a field. Moreover, with the combination of a liquid crystal panel and a color filter, vivid color display can be realized, so that researches have been made on a color display and the color display is partially realized in practical use.

As a driving method of such a liquid crystal display device, several kinds of methods can be considered, and recently, an active matrix driving method is chiefly used.

The liquid crystal display devices which are suitable for such an active matrix driving method have been well known. Referring to Fig. 3 to Fig. 5, a general constitution of the conventional liquid crystal display device will be explained briefly.

Fig. 3 is a partial plain view which mainly shows a distributional relationship between respective constitution components on a substrate (which is called as a pixel electrode substrate) at a side provided with a switching element in a conventional active matrix type liquid crystal display device. Also, this case shows an example that a switching element is a thin film transistor (TFT).

In Fig. 3, a reference numeral 11 shows a source electrode as a data electrode, 13 shows a gate electrode as a scanning electrode. These electrodes are formed on a suitable substrate,

for example, such as a glass substrate in a matrix shape. Also, a TFT 15 is formed on a region where these both electrodes cross each other, and reference numeral 17 in the figure shows a drain electrode of the TFT 15. The drain electrode 17 is connected to a pixel electrode 19 (shown with oblique lines in the figure).

Further, Fig. 4 is a cross sectional view in which a pixel electrode substrate shown in Fig. 3 is schematically shown by cutting along the line I-I shown in Fig. 3. It should be noted that hatching which shows a cross section is partially omitted to avoid complexity of drawings.

In the Fig. 4, reference numeral 21 shows a substrate, for example a glass substrate, 23 shows a gate insulating film, 25 shows amorphous silicon film, 27 shows a protective film, respectively.

Further, Fig. 5 is a cross sectional view which schematically shows a conventional liquid crystal display device constituted with a pixel electrode substrate explained with Fig. 3 and Fig. 4 and another substrate (which is also called as a common electrode substrate) having a common electrode which is prepared later. It should be noted that Fig. 5 shows an example of the liquid crystal display device used for color display. Also, to avoid complexity of the drawings, hatching which shows cross section is partially omitted in the drawing.

In Fig. 5, reference numeral 31 shows a second substrate. On the substrate 31, a color filter 33 for color display and a common electrode 35 are formed in this order. Also, in the drawing, reference numeral 37 shows an alignment film which is formed on each of counter surfaces of a pixel electrode substrate 21 and a common electrode substrate 31. Between these substrates 21 and 31, a liquid crystal 39 is sealed.

In the conventional liquid crystal display device, a region on which a TFT 15, a scanning electrode (gate electrode) 13, and a data electrode (source electrode) 15 are formed, protrudes from a surface of the substrate, thereby generating a convex portion 41. Further, there arises

no problem in the case of a common electrode of a liquid crystal display device for monochrome display. However, as shown in Fig. 5, in the case of using a color filter 33 at a liquid crystal injection side of a common electrode substrate, a concave portion 43 is generated between adjacent color filters. In this way, the conventional liquid crystal display device has continuous and periodic steps having about 1 to 2 μm on a surface of a liquid crystal sealing region side of one or both of substrates which are opposite to each other.

Moreover, as is apparent from Fig. 3, in the conventional liquid crystal display device, to prevent short between a pixel electrode 19 and a source electrode 11 or a gate electrode 13, it is necessary to separate the pixel electrode from these electrodes.

By the way, according to the conventional active matrix type liquid crystal display device mentioned above, one part of liquid crystal molecules is orientated in the direction which is not a desired orientation direction (hereinafter, it is referred to as a domain phenomenon), due to the reason described below. Because of this, image quality is impaired.

One reason of generating such a domain phenomenon is the above mentioned steps formed on a substrate. For example, if steps are constituted with the TFT portion which is protruded from a surface of the substrate by about 2μm, although the distance between opposed substrates varies depending on sorts of liquid crystal display devices, it is at most about 10 μm. Therefore, if there is a step of about 2μm on a substrate as mentioned above, dimensions of gaps for sealing of a liquid crystal in a portion having the step and in a portion having no step are different as a result. It seems that respective orientations of liquid crystal molecules in these both portions are different each other, thereby causing the domain phenomenon.

It can be considered that curve of electric force lines is another reason of causing the domain phenomenon. It will be explained with reference to Fig. 6.

In an active matrix type liquid crystal display device, a lot of gate electrodes are selected

in order, and data signals are respectively applied to source electrodes of a lot of pixels which are associated with the selected gate electrode. Now, a lot of pixels associated with one gate electrode become on state at every other pixel and the rest become off state. Fig. 6 shows a schematic view of the electric force lines in the case of driving the conventional liquid crystal display device in this way and it shows the case that a voltage is applied to the pixel electrode 19 to make it positive electric potential against a common electrode 37. The electric force lines which extend from the pixel electrode 19 to the common electrode 37 essentially generate between a pixel electrode of a driven TFT and a common electrode, and it seems that unnecessary electric force lines (in Fig. 6, curve of electric force lines shown with reference numeral 41) also generate between a driven TFT and a pixel electrode of a not driven TFT. An orientation direction of liquid crystal molecules in a region in which the unnecessary electric force lines are generated is different from that in a region in which normal electric force lines are generated, thereby causing the domain phenomenon. Such the unnecessary electric force lines also generate in an edge region of a pixel electrode in an off-state which is arranged along a data electrode to which on-signals are applied.

There is a reference in which such a domain phenomenon is regarded as a problem, researches are made to solve the problem, and the result is disclosed, for example, Japanese Patent Laid-Open No. 60-243633. According to the publication, when the domain phenomenon is generated, a gap between a source electrode of TFT and an edge of a pixel electrode is made as straight as possible to vanish it quickly. Further, in the case of a liquid-crystal display device for a color display, the gap which exists between adjacent color filters is performed with an alignment to oppose to a gap between the above mentioned source electrode and a pixel electrode at a side which is not driven by the source electrode near the source electrode.

[Problems to be solved by the Invention]

However, as mentioned above, the gap between a source electrode and a pixel electrode is made as straight as possible, thererby degree of freedom in a pixel arrangement of a liquid crystal display device is lost. Further, accuracy arrangement is necessary for arrangement of gaps which are precisely opposed to each other, so that it is not desirable in view of manufacturing process. Further, no measures against the domain phenomenon is considered in a portion where electric force lines are bent (shown with reference numeral 41 in Fig. 6). As a result, in this portion, display quality is impaired by nonconformity of an arrangement of liquid crystal molecules.

The present invention is accomplished in view of the above matter, and the purpose thereof is to propose a liquid crystal display device in which the domain phenomenon is not easily generated and if the domain phenomenon is generated, it will not be observed.

[Means to solve the Problem]

To accomplish the purpose, an active matrix driving type liquid crystal display device of the present invention provided with a pixel electrode substrate on which a switching element is provided and a common electrode substrate is characterized by forming an insulating layer having a flat surface on a surface of the above mentioned pixel electrode substrate, and a pixel electrode on the above mentioned flat surface of the insulating layer to be connected to the above mentioned switching element through a contact hole provided on the insulating layer.

When the embodiment of the present invention is executed, it is suitable to form an electric separation region of the above mentioned pixel electrode in upper region of the data electrode of the above mentioned switching element.

If a liquid crystal display device has a color display and a color filter is formed on a

common electrode substrate, it is suitable to form an insulating layer to flatten an irregularity between the color filter and a surface of the substrate, and a common electrode on the insulating layer.

[Operation]

According to the constitution, it is possible to cover an irregularity mainly constituted with a switching element, a scanning electrode of the switching element, a data electrode and a pixel electrode substrate surface of the switching element with an insulating layer having a flat surface. Therefore, since the gap for sealing of a liquid crystal between a pixel electrode substrate and a common electrode substrate has substantially the same measurement in every portion between both substrates, several conditions for orientation of a liquid crystal molecule will be the same. Therefore, the domain phenomenon due to the step can be prevented.

Further, since a switching element, and scanning and data electrodes of the switching element are covered with an insulating layer, a pixel electrode provided on the insulating layer can be formed up to the upper region of the switching element and the both electrodes are formed. Therefore, a separation region can be formed on a region which is formed over a scanning electrode or a region which is formed over a data electrode to electrically separate adjacent pixel electrodes.

In a suitable example of the present invention, an electric separation region formed in a direction parallel to the stripe direction of a data electrode of a switching element between adjacent pixel electrodes is provided inside a region over an insulating layer portion which is formed over the data electrode region. The data electrode and the scanning electrode are generally formed with metallic thin films having translucency. By doing this, it is possible to cover an electric separation region where a domain phenomenon is easily generated due to the curve of electric force lines, between pixel electrodes which are parallel to a data

electrode with these translucent metals. As a result, the domain phenomenon is not observed by a person who looks the display device.

[Embodiment]

Hereinafter, referring to Fig. 1 and Fig. 2, an embodiment of the active matrix type liquid crystal display device of the invention will be explained. Also, since each of drawings used in the following explanation is schematically shown for understanding of the invention, the present invention is not limited to only these examples of drawings. Also, in the respective drawings, the same mark designates the common constituent. Further, the same mark as the conventional one designates the same constituent as the conventional one.

<u>Constitution of a liquid crystal display device</u>

Fig. 1(A) is a partial plain view mainly showing arrangement of respective constituents on a substrate at a side where switching element is provided of an active matrix type liquid crystal display device of the present invention. It should be noted that in this case, an explanation is made in an example of which switching element is a thin film transistor (TFT).

In Fig. 1(A), reference numeral 11 is a source electrode as a data electrode, 13 shows a gate electrode as a scanning electrode. These electrodes are formed in a matrix shape on a suitable substrate such as a glass substrate. Also, in a region where these both electrodes cross each other, a TFT 15 is formed. In the drawing, reference numeral 17 becomes a drain electrode of the TFT 15.

Further, although not shown in Fig. 1(A), (explanation will be follow using Fig. 1(B)), the liquid crystal display device of the present invention is provided with an insulating layer having a flat surface which covers an irregularity constituted mainly with a source electrode

11, a gate electrode 13, a TFT 15, and a surface of a substrate, on a pixel electrode substrate, and a pixel electrode 51 (shown with oblique lines in Fig. 1(A)) on the insulating layer. Then, the pixel electrode 51 is connected to a drain electrode 17 under the insulating layer through a contact hole 53. Further, the pixel electrode 51 in this embodiment is formed as follows by making use of such an insulating layer. An electric separation region 55 in a direction parallel to a stripe direction of a source electrode between adjacent pixel electrodes 51 among respective pixel electrodes 51 which are linearly arranged along the stripe direction of the gate electrode 13 is formed in a region formed over a source electrode 11 in order to be formed inside the formation region of the source electrode. Therefore, the pixel electrode in this case exists also over a region where TFT 15 is formed.

Fig. 1(B) is a cross sectional view which shows an outline of a pixel electrode substrate shown in Fig. 1(A) which is cut along the line II-II shown in Fig. 1(A). It should be noted that hatching which shows a cross section is partially omitted to avoid complexity of drawings.

In the Fig. 1(B), reference numeral 21 shows a substrate, for example a glass substrate, 23 shows a gate insulating film, and 25 shows an amorphous silicon film, respectively. Also, reference numeral 57 shows the above mentioned insulating film to flatten an irregularity which is mainly constituted with a source electrode 11, a gate electrode 13, a TFT 15 and a substrate surface. Further, a contact hole 53 is formed in a region of the insulating layer 57 corresponding and over a drain electrode 17.

As an apparent from the Fig. 1(B), the electric separation region 55 between pixel electrodes can be formed over a source electrode because of having an insulating layer 57. Therefore, display data of one data electrode of a lot of source electrodes (data electrodes) in which display data is constantly written becomes a signal showing continuous high-level. If a domain phenomenon is generated for a long time between such a data electrode and a pixel

electrode in an off-state which along the data electrode, the domain phenomenon is interrupted by the source electrode, so that it will not be observed by a person who looks the liquid crystal display device from the side of a pixel electrode substrate.

When a liquid crystal display device is constituted with a substrate for a pixel electrode of this invention and a conventional common electrode substrate, the domain phenomenon due to steps will not be generated in the case of a liquid crystal display device in monochrome display. Further, the domain phenomenon due to the curve of electric force lines is interrupted by a gate electrode in a color display as well as a monochrome display. Therefore, the domain phenomenon is not observed by a person who looks the liquid crystal display device from the pixel electrode substrate side.

Also, in the case of a liquid crystal display device in a color display using a conventional common electrode substrate provided with a color filter as shown in Fig. 5 and a pixel electrode substrate of the present invention, there is no step at a side of a pixel electrode substrate, thereby display quality thereof is superior to the conventional one. It should be noted that it is suitable to form a common electrode substrate having a constitution shown in a cross section of Fig. 2 in the case that more excellent display is attempted to obtain in the liquid crystal display device in color display having such a constitution.

In Fig. 2, reference numeral 31 shows a glass substrate. On the glass substrate 31, a color filter 33 is provided. Further, a common electrode substrate regarding the present invention is provided with an insulating layer 61 and a common electrode 37 formed thereon. The insulating layer 61 having a flat surface covers a step in order to flatten the step mainly constituted with the color filter 33 and a surface of the substrate 31, on the glass substrate 31 including the color filter 33, and a common electrode 37 provided on the insulating layer 61.

The domain phenomenon due to a step will not be generated in a liquid crystal display

device in a color display according to the present invention which is formed by sealing a liquid crystal between a pixel electrode substrate shown in Fig. 1(A) and Fig. 1(B) and a common electrode substrate shown in Fig. 2. Also, if the domain phenomenon is generated due to a step in a contact hole portion 53 or the curve of electric forth lines in an electric separation region 55 between pixel electrodes, it will be interrupted by source and drain electrodes. As a result, the domain phenomenon will not be observed by a person who looks the liquid crystal display device from a pixel electrode substrate side.

Method of manufacturing a liquid crystal display device

Then, in order to promote understanding of a liquid crystal display device of the present invention, an example of manufacturing methods of the liquid crystal display device according to this embodiment of the present invention is described with reference to Fig. 1(B) and Fig. 2. It should be noted that since materials, forming methods, numerical value conditions, and the like, described below are only an example, the present invention will not be limited to these materials, forming methods, and numerical value conditions..

Using a general thin film formation technique, a TFT 15 as a switching element formed on a glass substrate 21, a scanning electrode of the TFT, and a data electrode 11 are formed. This step can be executed by a conventional manufacturing method of an active matrix type liquid crystal display device.

Then, an insulating layer 57 having a flat surface is formed on the glass substrate 21 on which the TFT 15 and both electrodes 13 and 11 are formed. In this embodiment, the insulating layer 57 is formed as follows.

The glass substrate 21 on which the TFT 15 and both electrode 13 and 11 are formed, is coated with polyimide varnish (SUNEVER 120 produced by Nissan Chemical Industries Ltd. is used) by spin coating method. Then, this is dried for about one hour at about 170℃.

It should be noted that as the condition for a spin coating method, film thickness of a flat portion of the glass substrate 21 of polyimide vanish is set to be 4 μm after drying. When polyimide vanish is applied to a step which is caused by the TFT 15 protruded from a surface of the substrate by about 2 μm under the above mentioned film formation conditions, the step is decreased to be 0.3 μm at a surface of a polyimide vanish. As a result, the protrusion of the TFT becomes smooth. Also, a film formation condition of the above mentioned polyimide vanish should be determined by taking shape of TFT and the like, viscosity of vanish used, or the like, into consideration, so that it should not be limited to the condition of this embodiment. Further, as a material to constitute an insulating layer 57, it should not be limited to the polyimide vanish of the present embodiment and another suitable material can be used.

Then, processing is performed on the insulating layer 57 formed as mentioned above. In the case of this embodiment, the processing is to form a contact hole 53 in a region corresponding to a drain region of the TFT 15, and to expose one part of these electrodes from the insulating layer 57 in order that a driving element prepared later is connected to a scanning and data electrodes. These processes are performed by using general photo-etching technique to form a resist mask and removing unnecessary portions of the insulating layer 57 with an etching solution or a rinse solution which is only for SUNEVER produced by Nissan Chemical Industries, Ltd.

Next, on the insulating layer 57, an ITO film is formed at a thickness of 1000Å by a suitable method, for example RF sputtering method or the like, and then the ITO film is processed into a predetermined shape (see Fig. 1(A)) by photo-etching technique to form a pixel electrode 51, thereby obtaining a pixel electrode substrate regarding the present invention as shown in Fig. 1(A) and Fig. 1(B).

On the other hand, a common electrode substrate as described above referring to Fig.

2 is formed as follows.

On a glass substrate 31, a color filter 33 is formed by a conventional known method. In this case, there is a step of about 2 μm between a surface of the color filter 33 and a surface of the substrate. In the same way as forming a pixel electrode substrate, a SUNEVER 120 is used to flatten the step under the same condition to remove unnecessary portion of the SUNEVER 120 in the same way as forming a pixel electrode substrate, thereby forming an insulating layer 69. On the insulating layer 69, a common electrode 37 is formed by a conventional known method.

An orientation treatment is performed on the pixel electrode subsrate and the common electrode substrate thus formed, thereafter, these substrates are mated with each other via a spacer. After sealing a liquid crystal into a gap between the substrates, sealing port is sealed to obtain a liquid crystal display device regarding the present invention.

It should be noted that the present invention is not limited to the above mentioned embodiment.

According to the above mentioned embodiment, a region in which pixel electrodes 51 are electrically separated from each other in a direction which is orthogonal to a stripe direction of a data (source) electrode is not formed over the scanning (gate) electrode but is formed in the same way as the conventional method. This is because that the scanning electrode is different from the data electrode in the following point: the scanning electrodes are driven one by one in line sequential and the driving speed is very fast for a person who looks a liquid crystal display device. Therefore, it is rare that the domain phenomenon caused at scanning electrode side is observed by a person who looks a liquid crystal display device. However, the separation region in a direction which is orthogonal to a stripe direction of the data electrode may be provided over the scanning (gate) electrode to interrupt the domain phenomenon generating in this portion by the gate electrode.

Further, in the above mentioned embodiment, an example that a switching element is TFT is described. However, it is apparent that the present invention can be applied to a liquid crystal display device in which the switching element is constituted as another non-linear switching element such as diode or MIM (Metal Insulator Metal).

[Effect of the Invention]

As is apparent from the above mentioned explanation, a liquid crystal display device of the present invention has an insulating layer for flatting the step due to the switching element or the like, and a pixel electrode formed on the insulating layer. Therefore, the domain phenomenon is not easily generated and also babble at sealing time of a liquid crystal is hard to be generated. Further, generation of the domain phenomenon can be prevented without making the gap between a pixel electrode and a source electrode as linear as possible, so that degree of freedom in a pixel arrangement will not be lost.

Also, an insulating layer can be formed to cover the switching element, or source and gate electrodes, thereby a pixel electrode can be formed up to the upper region on which source and drain electrodes are formed. Therefore, an electric separation region between pixel electrodes in which the domain phenomenon is easily generated, is formed over a source electrode, for example, and the domain phenomenon caused by the curve of electric force lines is interrupted by a source electrode.

Because of this, it is possible to propose a liquid crystal display device in which a domain phenomenon is not easily generated, and if the domain phenomenon is generated, it is hard to be observed. As a result, in comparison with the conventional liquid crystal display device, contrast characteristics and angle of visibility characteristics of a liquid crystal display device of the present invention is improved.

4. Brief Description of the Drawings

Fig. 1(A) and Fig. 1(B) show a plan view and a cross sectional view of principal portions used for an explanation of a liquid crystal display device of the invention.

Fig. 2 shows a cross section of a principal portion used for an explanation of a liquid cyrstal display device of the present inveiont, and a cross section of one part of a common electrode substrate.

Fig. 3 to Fig. 5 are used for an explanation of a convenitonal liquid cyrstal display device, and Fig. 3 and Fig. 4 are a plan view and a cross sesctional view showing one part of a pixel electrode substrate, and Fig. 5 is a cross sectional view showing one part of a liquid crystal display device.

Fig. 6 is used for an explanation of a prior art and this invention.

11 ... data electrode (source electrode)

13 ... scanning electrode (gate electrode)

15 ... switching element

17 ... drain electrode

23 ... gate insulating film

25 ... amorphous silicon

51, 51a, 51b ... pixel electrode

53... contact hole

55 ... electric separation region between pixel electrodes

57, 61 ... insulating layer having a flat surface